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FORAMINIFERA ASSEMBLAGES: PROXIES FOR PALAEOENVIRONMENTAL DETERMINATION -AN EXAMPLE FROM MAASTRICHTIAN SEDIMENTS OF *ORHUA* AND ENVIRONS.

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ABSTRACT
The study area which is part of the *Nkporo* Group lies within the Benin flank of the Anambra basin. This study aimed at reconstructing the palaeo-environment of the Nkporo shale outcropping in this part of the basin through field relationship and micropalaeontological studies. The field data shows that the shales are fissile, light to dark grey with intercalations of fine to medium grained sands. The fissility of the shale suggests that it was deposited in low energy environment, distal to proximal lagoon environment. The occurrences of these sandy intercalations within the shales are likely indications of fluvial influence during deposition. Some selected shale samples were subjected to micropalaeontological analysis. Foraminifers associated with shales were extracted, identified, and used for dating included: *Globigerinelloides subcarinaa (69.3Ma); Heterohelix navarroensis (68.7Ma); Abathomphalus intermedius (65.6Ma); Gansserina gansseri(68.8Ma), Guembelitria cretacea (66.9Ma), Pseudoguembelina palpebra (67.7Ma), Globotruncanella havanensis (69.4Ma),* and *Globotruncanella citae (68.6Ma).* Based on this the age of shales in *Orhua* and environs is given as Maastrichtian to Early Paleocene. The occurrence of *Bulimina marginata* and *Virgulina squamosa* which are benthic foraminifera suggests normal shelf environment of deposition.

KEYWORDS: Foraminifera, Palaeoenvironmental Determination, Orhua, Maastrichtian.

INTRODUCTION
Benthic and Planktonic Foraminifers are widely used as tools to reconstruct palaeoenvironments and relative dating of sedimentary rocks. Since the Cambrian times, they diversified as part of the burst in development of the kingdom Protista. From that time onward, they are present in a wide range of environments, from shallow brackish waters to the deepest parts of the ocean. The calcareous or arenaceous tests of benthic foraminifers lend them good fossilization potential, which in combination with the often considerable abundances makes them useful tools in exploration. In contrast to planktonic foraminifers, which initially were mainly employed as biostratigraphical markers, and now as tools in palaeo-oceanographical studies, benthic foraminifers were considered to reflect salinity, temperature and depth of the depositional basin.

The sedimentary outcrops of shales and sandstones in Orhua and environs (fig.1) were mapped and fossil content (foraminifera) extracted to ascertain their palaeoenvironments of deposition. The study area is located within the Benin flank (south western part) of the Anambra basin (fig.1).

Geologic Overview
The Anambra Basin is a Cretaceous/Tertiary basin, which is the structural link between the Benue Trough and the Tertiary Niger Delta Basin. Spatially, it is the sedimentary wedge bordered by the Abakaliki anticlinorium to the East, the basement rock and the Benue hinge line to the north and northwest respectively. The formation of this southern sedimentary basin followed the break-up of the South American and African continents in the Early Cretaceous (Murat, 1972; Burke, 1996). Various lines of geomorphologic, structural, stratigraphic and palaeontologic evidence have been presented to support a rift model (King, 1950; Bullard et al., 1965; Reyment, 1969; Burke et al., 1971, 1972; Fairhead and Green, 1989; Benkhelil, 1989; Guiraud and Bellion, 1995).

The stratigraphic history of the region is characterised by three sedimentary phases (Short and Stäuble, 1967; Murat, 1972; Obi et al. 2001; fig.2) during which the axis of the sedimentary basin shifted. These three phases were: (a) the *Abakaliki-Benue* Phase (Aptian-Santonian), (b) the *Anambra-Benin* phase (Campanian-Mid Eocene), and (c) the *Niger Delta* phase (Late Eocene-Pliocene). The more than 3000 metres of rocks comprising the *Asu* River Group and the *Ezeaku* and *Awgu* Formations, were deposited during the first phase in the

Abakaliki-Benue Basin, the *Benue* valley and the *Calabar* Flank (fig. 2). The second sedimentary phase resulted from the Santonian folding and uplift of the *Abakaliki* region and dislocation of the depocenter into the *Anambra* platform and *Afikpo* region. The resulting succession comprises the *Nkporo* Group, *Mamu* Formation, *Ajali* Sandstone, *Nsukka* Formation, *Imo* Formation and *Ameki* Group (fig. 2). The third sedimentary phase credited for the formation of the petroliferous *Niger Delta* commenced in the Late Eocene as a result of a major earth movement that structurally inverted the Abakaliki region and displaced the depositional axis further to the south of the Anambra Basin

The second sedimentary phase carries the focus of this study. The formations of the Campanian *Nkporo* Group reflect a funnel-shaped shallow marine shelf setting that graded into channeled low energy marshes. The concave inward shape of the coastline allowed for a gradual filling by minor amount of sediment brought in by short rivers, that were carried along by north-eastward converging lonshore drifts. Extensive coastal swamps developed behind the poorly developed foreshores and shorefaces now known as the *Enugu* shale. According to Reijers (1996) the shallow open marine shelf sea was alternatively storm- and tide-dominated and in many respects comparable to that prevailing on the Nigeria's southwest coast. The Maastrichtian coal-bearing *Mamu* and the *Ajali* Formations formed during the overall regression of the *Nkporo* Group with associated progradation. The *Nsukka* Formation, which overlies the *Ajali* Sandstone, begins with coarse- to medium-grained sandstones and passes upward into well-bedded blue clays, fine-grained sandstones, and carbonaceous shales with thin bands of limestone (Reyment, 1965; Obi *et al*., 2001). Obi *et al*. (2001) used sedimentological evidence to suggest that the *Nsukka* Formation represented a phase of fluvio-deltaic sedimentation that began close to the end of the Maastrichtian and continued during the Paleocene. The *Nsukka* Formation (Paleocene) marks the onset of another transgression and documents the return of paludal conditions. Sedimentation was mainly of fluvial origin though punctuated at the height of transgressive phases by marine flooding. The *Imo* shales reflect shallow-marine shelf conditions in which foreshore and shoreface sands are occasionally preserved. The *Imo* Formation consists of blue-grey clays and shales and black shales with bands of calcareous sandstone, marl, and limestone (Reyment, 1965). Ostracode and foraminiferal biostratigraphy (Reyment, 1965), and microfauna recovered from the basal limestone unit (Adegoke *et al*., 1980; Arua, 1980) indicate a Paleocene age for the formation. Lithology and trace fossils of the basal sandstone unit reflect foreshore and shoreface (Reijers *et al*., 1997) The Eocene *Ameki* Group marks the return to regressive conditions.

Local Geologic Setting

Orhua and environs is a sedimentary terrain with two major lithologies namely: shales and sandstone units interbedded with occasional sandy-shale units (fig.3). Of these two, the sandstone unit is younger.

The underlying shales are usually dark brown to dark grey in colour, thickly to thin laminated, and fissile. The field relationship is that of a sharp contact and mode of occurrence is low-lying outcrops buried by thick overburden and exposed by the erosive effects of springs and streams. A number of fresh water springs sourced within the sharp contacts between underlying shale, overlying sandstone, and the water table (fig.3).

The younger Lithologic unit sandstone is either ferroginized or non-ferroginized. The ferroginized sandstone ranges in colour from reddish brown to yellow, and black to grey. Intercalations of carbonaceous shales occur in some cases. Grain sizes ranged from fine to medium, and rounded to sub-angular. The non-ferroginized sandstone ranges in colour from white to yellowish colouration with angular to sub-angular in shape. It comprises of quartz, feldspar, and mica. It occurred as a low lying outcrop exposed by river channel.

MATERIALS AND METHODS

Field Study, Sample Collection and Processing: The field study involved a detailed geologic mapping on a scale of 1:10,000. Ten composite sedimentary successions outcropping (fig. 3) in Orhua and environs in Edo State, Southwestern Nigeria (fig.1) were measured, to gather data on the textural and Lithologic variations. Twenty samples from shale and sandy shale horizons were collected and processed for foraminiferal contents. The samples each weighing between 150g was prepared for foraminiferal analyses. They were processed, dried and weighed prior to wet sieving through a 63µm sieve.

Foraminifers from un-lithified samples were soaked in a 3% solution of hydrogen peroxide with a small amount of Calgon added and then washed with tap water over a 63-µm sieve (Lower Eocene interval) or a 45-µm sieve (basal Eocene-Upper Cretaceous interval). Semilithified samples were first partially fragmented by hand and then soaked in hydrogen peroxide and Calgon before washing. More cemented samples were disaggregated by

mild heating and treatment with H_2O_2. After every use, the sieve was dipped in a dilute solution of methyl blue dye to identify contaminants from previous samples. After washing, all samples were collected on filter paper and then dried on a hot plate at ~50°C. The resulting fractions were then sieved through a 150µm sieve and all foraminifers retained on the sieve were picked. The >63µm fraction was dried, weighed, and repeatedly halved in a sediment splitter until a fraction containing a minimum 200 specimens was obtained.

Species identification for planktonic foraminifers were generally made on the >250-µm and >150-µm size fractions. Two picking trays per sample from >250-µm size fraction or the >125-µm fraction (Paleogene-Late-Cretaceous) were examined for identification and abundance estimation of benthic foraminifers.

RESULTS AND DISCUSSION

Age Determination

The numerical ages were estimated from the planktonic foraminifera correlated with the global zonations scheme. The zonations used for the lower Cretaceous planktonic foraminifera is based on the tropical zonal scheme (Caron, 1985) while for the upper Cretaceous on zonal schemes (Silva and Sliter, 1999). On these bases the numerical ages stated below considering the first and last appearance of the foraminiferal species were established (Table 1; fig.4). The age range of 65.8 to 69.3Ma corresponds to Maastrichtian to Early Paleocene which is comparable to that already presented by Nwajide, 1990 (fig. 2).

Table 1: Planktonic Foraminifera Relative Ages

Planktonic foraminifera	Relative Age(Ma)
Globigerinelloides subcarinaa	69.3Ma
Gansserina gansseri	68.8Ma
Globotruncanella citae	68.6Ma
Abathomphalus intermedius	65.8Ma
Guembelitria cretacea	66.9Ma
Globotruncanella havanensis	69.4Ma
Pseudoguembelina palpebra	67.7Ma
Heterohelix navarroensis	68.7Ma

Environment of Deposition

The environment of deposition of the *Nkporo* shale outcropping at *Orhua* was determined using the following characteristics of benthonic foraminifers: (i) Changes in species diversity, (ii) Planktic to Benthic ratios signals {P/B ratio (%)}, (iii) Shell-type ratios and, test morphology.

The occurrence of *Bulimina marginata* and *Virgulina squamosa* which are benthic foraminifera suggests normal shelf environment of deposition. Most of the species of the genera *Buliminella and Bulimina* are only found abundant in certain shelf environments where they are dominant (Seiglie, 1968). The shelf environments range in depth from10 to 80m. The planktonic *Globotruncanella* species is also suggestive of shallow shelf environment. The species diversification from benthic to planktonic forms is an indication of normal shelf environment typical of the *Nkporo* shale.

The Planktic-Benthic (P/B) ratio ranges between 5 to 50% with values dominating between 15 to 25% (Table 2). Using modern day analogue points to change in water depth, it can be inferred that the sediments were deposited between an inner neritic to middle neritic environmental condition (fig. 5). These are said to be associated with shallow normal shelf environment.

The shell types of the foraminifera recovered from the outcrop samples ranges from non-keeled, single keeled, to double keeled morphological groups, with the non-keeled morphology dominating. The non-keeled planktonic foraminifera are believed to be shallow water dwellers. Therefore the environment of deposition is shallow normal shelf environment.

Test morphology was also used for Palaeoenvironmental reconstruction. Two types of shell morphology were recognized; thin shelled (delicate and elongate) and thicker shelled (heavily ornamented and globular). The

thicker shelled, heavily ornamented, and globular shaped foraminifera are indicative of a shallow marine environment.

Tables 3 and 4 indicate the abundance and diversity of planktonic and benthonic foraminifers respectively. These values were used as the biofacies zonations and estimating palaeo-water depth situations and calculating P/B ratios discussed earlier.

CONCLUSIONS

Micropalaeontological sampling and the analysis of the microfauna allowed the confirmation and/or attribution of new ages for the Upper Cretaceous detritic deposits, and especially the identification of the base of the Maastrichtian. The Late Cretaceous fauna from the upper sandy shale level (in the uppermost part of the succession) documents micropalaeontologically Upper Maastrichtian. It's considered that, due to the current outcropping condition of the deposits, there is no real possibility to palaeontologically establish the presence of the Paleocene, respectively that of a continuous sedimentation at the Cretaceous –Paleogene boundary.

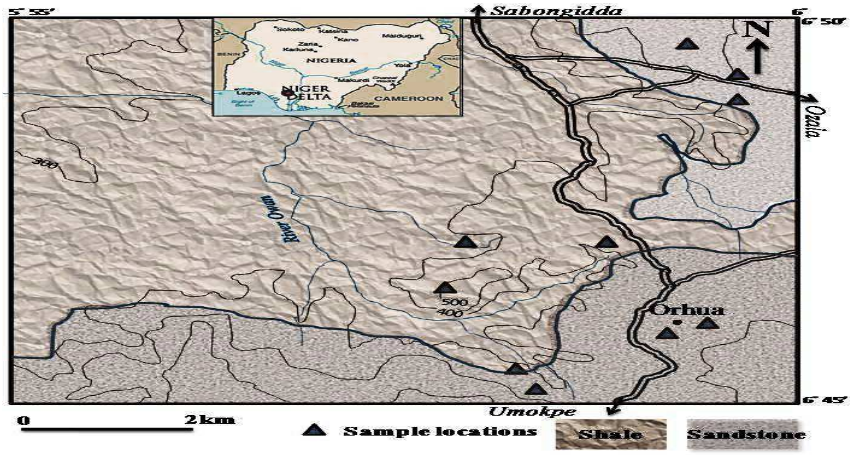

Figure 1: Outline Geologic Map of the Study Area

m.y	AGE	ABAKALIKI – ANAMBRA BASIN	AFIKPO BASIN
30	Oligocene	Ogwashi-Asaba Formation	Ogwashi-Asaba Formation
54.9	Eocene	Ameki/Nanka Formation/ Nsugbe Sandstone (Ameki Group)	Ameki Formation
65	Palaeocene	Imo Formation Nsukka Formation	Imo Formation Nsukka Formation
73	Maastrichtian	Ajali Formation Mamu Formation	Ajali Formation Mamu Formation
83	Campanian	Npkoro Oweli Formation/Enugu Shale	Nkporo Shale/ Afikpo Sandstone
87.5	Santonian		Non-deposition/erosion
88.5	Coniacian	Agbani Sandstone/Awgu Shale	
93	Turonian	Eze Aku Group	Eze Aku Group (incl. Amasiri Sandstone)
100	Cenomanian – Albian	Asu River Group	Asu River Group
119	Aptian Barremian Hauterivian	Unnamed Units	
	Precambrian	Basement Complex	

Figure 2: Correlation Chart for Early Cretaceous-Tertiary strata in southeastern Nigeria (modified after Nwajide, 1990).

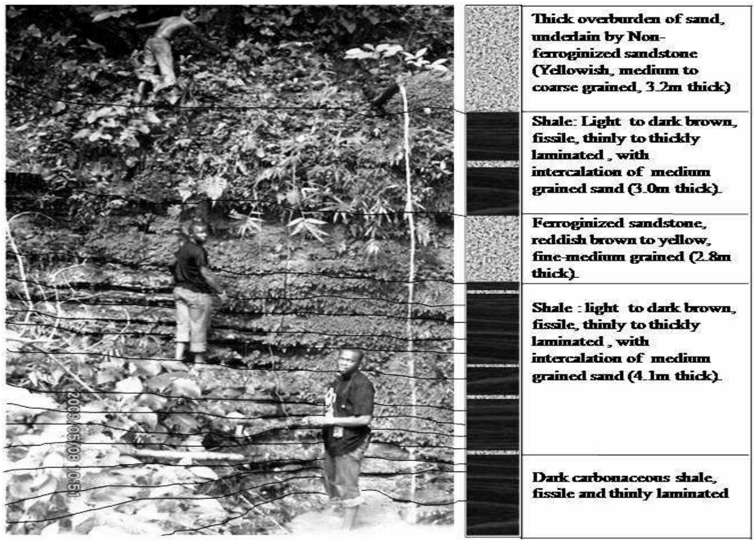

Figure 3: Outcrop of Sedimentary Succession at Orhua (L14).

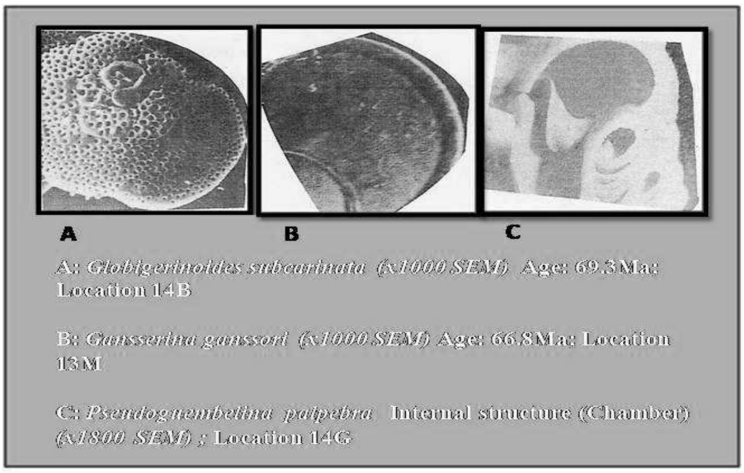

Figure 4: Photomicrographs of some identified Foraminifera from the Study Area.

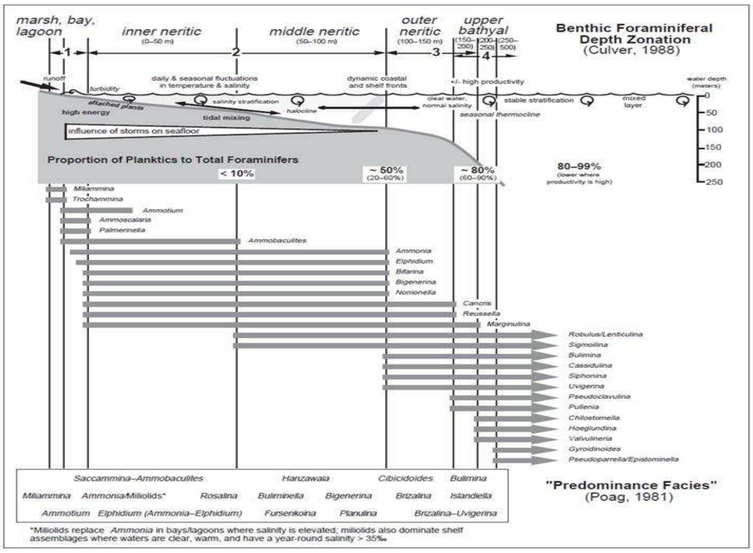

Figure 5: Benthic Foraminiferal Depth Zonation based on Culver (1988).

Table 2: Foraminiferal Planktic-Benthic Ratios

Sample Number	Number of Species Diversity	Total Number of Individual Abundance	Number of Individual Planktonic	P/B Ratio (%)
L13N	02	02	1	50.0
L13M	11	27	8	29.6
L13L	08	17	4	23.5
L13K	11	25	6	24.0
L13J	13	28	6	21.4
L13I	07	24	2	8.30
L13H	07	16	2	12.5
L13G	11	21	3	14.3
L13F	09	20	3	15.0
L13E	12	16	3	18.8
L13D	12	17	7	41.2
L13C	08	18	1	5.60
L13B	08	25	2	08.0
L13A	09	28	3	10.7
L14A	03	05	1	20.0
L14B	09	27	4	14.8
L14C	02	03	0	00.0
L14D	14	36	4	11.0
L14E	08	19	4	21.0
L14G	09	27	5	18.5

Table 3: Planktonic Foraminifera Species Abundance and Diversity

Sample Number	**Planktonic Foraminifera Species**								**Species Abundance**	**Species Diversity**
	1	2	3	4	5	6	7	8		
L13N	-	-	-	-	-	v	-	-	01	1
L13M	v	v	v	v	v	v	v	v	13	8
L13L	-	v	-	-	-	v	v	v	09	4
L13K	v	v	v	-	v	-	v	v	10	6
L13J	-	v	v	v	v	v	v	v	11	6
L13I	-	-	-	v	-	v	-	-	08	2
L13H	v	-	-	v	-	v	-	-	05	2
L13G	-	-	-	v	-	-	-	-	07	3
L13F	-	-	v	-	v	-	v	-	08	3
L13E	v	-	-	v	-	-	-	v	04	3
L13D	v	v	v	v	v	-	v	v	09	7
L13C	-	-	-	-	v	-	-	-	05	1
L13B	-	-	-	-	v	-	-	v	07	2
L13A	-	v	-	-	v	-	-	v	08	3
L14A	-	-	-	-	-	v	-	-	02	1
L14B	v	-	v	v	-	v	-	-	06	4
L14C	-	-	-	-	-	-	-	-	00	0
L14D	v	v	-	v	-	-	v	-	12	4
L14E	v	v	-	v	v	-	-	-	10	4
L14G	v	-	v	-	v	v	v	-	14	5

Legend	
Species 1	*Globigerinelloides subcarinaa* (BRONNIMANN)
Species 2	*Gansserina gansseri* (BOLI)
Species 3	*Globotruncanella citae* (BOLI)
Species 4	*Abamophalus intermedius* (BOLI)
Species 5	*Guembelina cretacea* (CUSHMAN)
Species 6	*Globomuncanuella havanesis* (VOORWIJK)
Species 7	*Pseudoguembelina palpebra* (BRONNIMANN AND BROWN)
Species 8	*Heterohelix navarroensis* (LOEBLICH)

Table 4: Benthic Foraminifera Species Abundance and Diversity

Sample Number	Benthic Foraminifera Species											Species Abundance	Species Diversity
	1	2	3	4	5	6	7	8	9	10	11		
L13N	-	-	√	-	-	√	-	-	-	-	-	01	01
L13M	-	-	-	√	-	-	-	√	-	√	-	14	03
L13L	-	-	√	-	√	-	√	-	-	√	-	8	04
L13K	√	-	√	√	-	√	-	-	-	-	√	15	05
L13J	√	√	-	√	√	√	-	√	-	√	-	17	07
L13I	-	√	-	-	√	-	√	√	-	√	-	16	05
L13H	√	-	√	√	-	-	√	-	-	-	√	11	05
L13G	√	-	√	√	√	-	√	√	√	√	-	14	08
L13F	-	-	-	√	√	√	√	√	-	-	√	12	06
L13E	√	-	√	√	√	√	√	-	√	√	√	12	09
L13D	-	√	-	√	-	√	√	√	-	-	-	08	05
L13C	-	√	√	-	√	√	√	-	-	√	√	13	07
L13B	√	-	-	√	-	√	√	-	√	-	√	18	06
L13A	√	-	√	-	√	-	√	-	√	-	√	08	03
L14A	-	-	-	-	-	-	-	√	-	-	√	03	02
L14B	-	√	-	√	-	-	√	-	√	-	√	21	05
L14C	-	-	-	-	-	√	√	-	-	-	-	03	02
L14D	√	√	-	√	√	√	√	√	√	√	√	24	10
L14E	√	-	√	-	-	√	-	-	-	-	√	09	04

Legend	
Species 1	*Nonionina canariensis d'orbigny* (Haplophragmoides CUSHMAN)
Species 2	*Spirolima aggalinans d'orbigny* (Ammobuculity CUSHMAN)
Species 3	*Trochammaina proteus, kaner* (Trochamminoides, CUSHMAN)
Species 4	*Vernevilina bradgi,* (CUSHMAN)
Species 5	*Gandyrina bulletta,*(JONES)
Species 6	*Textularia barrette*(CARSEY)
Species 7	*Buliminad marginata,*(d'ORBIGNY)
Species 8	*Virgulina squamosa,*(d'ORBIGNY)
Species 9	*Vernebilina spinulosa,* (REUSS)
Species 10	*Uvigerina pygmea,* (d'ORBIGNY)
Species 11	*Uvigerina cristata,*(MARSSON)

REFERENCES

Adegoke, O.S., Arua, I., Oyegoke, O., 1980. Two new nautiloids from the Imo Shale, (Paleocene) and Ameki Formation (Middle Eocene), Anambra State, Nigeria. Journal of Mining and Geology 17, 85–89.

Arua, I., 1980. Palaeocene Macrofossils from the Imo Shale in Anambra State, Nigeria. Journal of Mining and Geology 17, 81– 84.

Benkhelil, J., 1989. The origin and evolution of the Cretaceous Benue Trough (Nigeria). Journal of African Earth Sciences 8, 251–282.

Bullard, E.C., Everett, J.E., Smith, A.G., 1965. Fit of the continents around the Atlantic. Philosophical Transactions of the Royal Society London A 258, 41–51.

Burke, K.C., 1996. The African Plate. South African Journal of Geology 99, 341–409.

Burke, K.C., Dessauvagie, T.F.J., Whiteman, A.J., 1971. The opening of the Gulf of Guinea and the geological history of the Benue depression and Niger delta. Nature Physical Science 233, 51–55.

Burke, K.C., Dessauvagie, T.F.J., Whiteman, A.J., 1972. Geological history of the Benue valley and adjacent areas. In: Dessauvagie, T.F.J., Whiteman, A.J. (Eds.), African Geology. University of Ibadan Press, Nigeria, pp. 187–218.

Caron, M., 1985. Cretaceous planktic foraminifera. *In* Bolli, H.M., Saunders, J.B., and Perch-Nielsen, K. (Eds.), Plankton Stratigraphy: Cambridge (Cambridge Univ. Press), 17-86.

Culver, S. J., 1988. New foraminiferal depth zonation of the northwestern Gulf of Mexico: Palaios, V. 3, p. 69–85.

Fairhead, J.D., and Green, C.M., 1989. Controls on rifting in Africa and the regional tectonic model for the Nigeria and East Niger rift basins. Journal of African Earth Sciences 8, 231–249.

Guiraud, R., and Bellion, Y., 1995. Late Carboniferous to Recent geodynamic evolution of the West Gondwanian, Cratonic, Tethyan margins. In: Nairn, A.E.M. et al. (Eds.), The Ocean Basins and Margins (vol. 8), The Tethys Ocean, pp. 101–124.

King, L.C., 1950. Outline and disruption of Gondwanaland. Geological Magazine 87, 353–359.

Murat, R.C., 1972. Stratigraphy and paleogeography of the Cretaceous and Lower Tertiary in southern Nigeria. In: Dessauvagie, T.F.J., Whiteman, A.J. (Eds.), African Geology. University of Ibadan Press, Nigeria, pp. 251–266.

Nwajide, C.S., 1990. Cretaceous sedimentation and palaeogeography of the Central Benue Trough. In: Ofoegbu, C.O. (Ed.), The Benue Trough Structure and Evolution. Friedr. Vieweg and Sohn, Braunchweig/Wiesbaden, pp. 19–38.

Obi, G.C., Okogbue, C.O., Nwajide, C.S., 2001. Evolution of the Enugu Cuesta: A tectonically driven erosional process. Global Journal of Pure Applied Sciences 7, 321–330.

Reijers, T.J.A. 1996. Selected Chapters on Geology: with notes on Sedimentary Geology, Sequence Stratigraphy and three case studies and a field guide. S.P.D.C. Corporate Reprographic Services, Warri, Nigeria. 197.

Reijers, T.J.A., Petters, S.W., Nwajide, C.S., 1997. The Niger Delta Basin. In: Selley, R.C. (Ed.), African Basins. Elsevier, Amsterdam, pp. 151–172.

Reyment, R.A., 1965. In: Aspects of the Geology of Nigeria. University of Ibadan Press, Nigeria, p. 145.

Reyment, R.A., 1969. Ammonite biostratigraphy, continental drift and oscillatory Transgressions. Nature 224, 137–269.

Seiglie, G.A. 1968. Foraminiferal Assemblages as indicators of Organic Carbon Content in Sediments or of Water Pollution. American Assoc. Petr. Geol., Bull., 52 (11): 2231-2241.

Short, K.C., Stäuble, A.J., 1967. Outline of geology of Niger delta. American Association of Petroleum Geologists Bulletin 51, 761–779.

Silva, I. and Sliter, W.V. 1999: Cretaceous Planktic Foraminifera from the Naura Basin. Elsevier Publishing Co. Amsterdam. Pp136-144.